

# WHAT COULD BE CAUSING GLOBAL OZONE DEPLETION?

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## ABSTRACT

The reported decline trend in global ozone between 1970 and 1986 may be in part an artifact of the analysis; the trend value appears to depend on the time interval selected for analysis--in relation to the 11-year solar cycle. If so, then the decline should diminish as one approaches solar maximum and includes data from 1987 to 1990. If the decline is real, its cause could be the result of natural and human factors other than just chlorofluorocarbons (CFCs).

## INTRODUCTION

The Ozone Trends Panel (OTP) of NASA, after a massive re-analysis of data from ground stations and satellites, announced the existence of a declining trend in northern hemisphere ozone of about 0.2% per year over the 17-year period from 1970 to 1986.<sup>1</sup> The result was announced at a press conference in March 1988, but the underlying analysis has not yet been published. Nevertheless, as a result of the announcement and subsequent press reports, it has become widely accepted that there has already been a global decline of stratosphere ozone caused by the release of CFCs into the atmosphere. Based on this impression, far-reaching international actions are contemplated to phase out quickly the production of CFCs and other chemicals.

The ozone trend analysis must, of course, eliminate the much larger natural variations: the seasonal changes, quasi-biennial oscillations (QBO), 11-year solar cycle effects, major volcanic eruptions, and even the after-effects of atmospheric nuclear testing. One should also be aware that ozone trends, like climate trends, may depend on the choice of time interval selected for analysis.<sup>2</sup>

## DEPENDENCE OF THE TREND ON THE METHOD OF ANALYSIS

While the OTP Report itself is not yet available, a parallel report from the Center for Applied Mathematics of Allied-Signal, Inc. was distributed at the UNEP Ozone Science Meeting at The Hague in October 1988. The Allied study<sup>3</sup> deals with many of the corrections necessary to establish the existence of a secular trend. It should be noted that the study models the trend as a linear ramp function, beginning in December 1969; the trend is assumed to be zero before that date. (This procedure is suggested by model calculation of CFC effects rather than by any measured stratospheric chlorine concentrations.)<sup>4</sup> Here we will examine primarily: (1) the solar flux correction and (2) the effect of choice of time period on the ozone trend result.

The Allied study uses the solar 10.7-cm radio flux as a proxy for the solar UV flux, for which a continuous data series is not available. Since the radio flux has no influence whatsoever on atmospheric ozone, the proxy is clearly one of convenience. (The OTP,

on the other hand, used the sunspot number as a proxy for the "effective" UV flux.) The correlation between the radio flux and the relevant UV flux is problematic <sup>5</sup>, making it difficult to judge the adequacy of the solar flux correlation.

The main results of the Allied study can be derived from their sensitivity analyses, shown in their table 2<sup>3</sup>:

- o The estimated change in total ozone (30-64 N) over the 17 years (between 1970-86) is -1.9%, which is less than the reported OTP result.
- o About half of the change, -0.9%, comes from using a "multiple trend" ramp function (where the coefficient of the ramp function is varied according to the month).
- o Another half of the change, 1.0%, comes from the inclusion of post-1982 data; the 13-year change between 1970 and 1982 is only -0.5%, i.e., -0.04% per year.
- o Excluding pre-1965 data, as was done in the OTP analysis, would make the 17-year decline (1970-86) more negative by 0.6%, i.e., -2.5%.

To explain the surprisingly strong dependence of the trend result on the choice of time period, the authors suggest natural causes, such as El Nino or volcanism, or unknown man-made causes. <sup>3,6</sup> Another simpler explanation may be that the 1970-86 period covers only 12.5 solar cycles and includes two solar flux decreases vs. one increase; figure 1 shows the strong dependence on sunspot number of total ozone observed in different zones <sup>7</sup>.

If this hypothesis is correct and the reported ozone decline <sup>1,3</sup> is partly due to the analysis procedure, then one would predict a diminished global ozone decrease if the analysis includes the years from 1987 up to 1990 as we reach a solar cycle maximum. An answer should thus be forthcoming soon.

(However, even if the observed ozone trend were then to go to zero, this would not rule out that increased use of CFCs will affect the stratospheric ozone layer sometime in the future. For example, the AER one-dimensional CFC-ozone model predicts change of only -0.25% over the period 1970-86. <sup>3</sup> Since the standard error of this prediction is 1.03%, it would be consistent with a zero observed ozone trend or even a small positive trend.)

#### POSSIBLE CAUSES OF A REAL TREND

If, on the other hand, the ozone secular trend is real, then there could be several possible causes, in addition to CFCs; they might be distinguished by measurements of ozone changes with altitude, latitude, and time.

- o Anthropogenic factors other than CFCs might decrease ozone levels. One such factor is methane from various human activities. Like CFCs, methane has a long tropospheric lifetime and percolates into the stratosphere, where it participates in ozone chemistry and eventually produces water vapor <sup>8</sup>. Since tropospheric methane has increased by about 100% in the past century, stratospheric water vapor should have increased also.

Certainly, there has been an increase in stratospheric CO<sub>2</sub> as a result of human activities, such as fossil fuel burning. As a consequence, one would expect increased radiative heat loss from the stratosphere and an effect of these colder temperatures on ozone chemistry.

I have speculated elsewhere<sup>9</sup> that such cooling, coupled with increased stratospheric humidity, could lead to the formation of polar stratospheric clouds (PSCs) that are believed to be essential in causing the Antarctic ozone hole (AOH). Thus, the AOH may indeed be due to human activity, but controlled now by stratospheric temperature and humidity rather than by increasing CFC concentrations.

Another source of water vapor (and cirrus) could be commercial jet aircraft that increasingly penetrate into the lower stratosphere. While current theory<sup>10</sup> does not envisage ozone destruction from aircraft at that altitude, current theory considers only homogenous (gas-phase) reactions and not yet heterogeneous reactions with particulates and ambient aerosols.

o Natural effects related to the variability of solar cycles may also be responsible for an observed ozone decline. The analyses<sup>1,3</sup> implicitly assume perfect correlation between the relevant solar UV and the proxies (whether sunspot number or radio flux), and are not equipped to deal with long-term changes in the correlation.

This last observation leads to an interesting aside. Solar cycles have varied greatly in the past<sup>11</sup> (see figure 2). In recent times, sunspot numbers have been as low as 40 (in 1817) and as high as 190 (in 1958) at the peak of the cycle. During the Maunder Minimum (1645-1715) sunspots were essentially absent. This suggests that there could have been substantial changes in average ozone levels in the past<sup>12</sup>, approximating those feared to result from the release of CFCs. It would be interesting, therefore, to search the historical records for any biological consequences to humans, agricultural crops, or marine life, that have been hypothesized as having been caused by low ozone levels.

## REFERENCES AND NOTES

- 1 NASA Ozone Trends Panel Executive Summary, R.T. Watson, Chm., March 1988, and press release. See summary by R.A. Kerr, "Research News," Science, March 25, 1988.
2. Singer, S.F., "Stratospheric ozone decreases: Doubts about causes and consequences," letter submitted to Science, April 12, 1988 (unpublished).
3. Bishop, L., W.J. Hill, and M.A. Marcucci, "An Analysis of the NASA Ozone Trends Panel Dobson Total Ozone Data over the Northern Hemisphere," Center for Applied Mathematics, Allied Signal, Inc., August 3, 1988. (see also R. Bojkov et al., J. Geophys Res. (1990), in press.) *I thank the authors for additional information and critical discussion.*
4. *Shifting the starting date of the ramp to 1965 reduces the trend by 40%; a 1975 data steepens it by 50%. (private communication, March 28, 1989.)*

5. *The Allied study refers to the UV-B flux, which is clearly inappropriate. The relevant region is in the far-UV and involves mainly the Runge-Schumann bands and continuum in the generation of ozone, and the Hartley-Huggins bands in its destruction. See also reference 12.*

6. Symonds, R.B., W.I. Rose, and M.H. Reed, "Contributions of Cl- and F-bearing gases in the atmosphere by volcanoes," Nature, 334, 415 (1988); *Volcanoes contribute particulates as well as gases, including chlorine compounds.*

(See also B.J. Finlayson-Pitts, M.J. Ezell, and J.N. Pitts, Jr., "Formation of chemically active chlorine compounds by reactions of atmospheric NaCl particles with gaseous NO and ClONO," Nature, 334, p. 241 (1989). *Ocean spray could be another contributor to stratospheric chlorine.*)

7. Angell, J.K., "On the relation between atmospheric ozone and sunspot number," J. Climate (1989).

(See also R.J. Angione, E.J. Medeiros, and R.G. Roosen, "Stratospheric ozone as viewed from the Chappuis band," (1976); *Stratospheric ozone data have been reported for the period 1912-1950 from stations in California and Chile, showing variations of as much as 20-30% on time scales changing from months to decades.*)

8. Singer, S., "Stratospheric water vapor increase caused by human activities," Nature, 223, p. 543 (1971).

(See also D.J. Hoffman, "Increase in the stratospheric background sulfuric acid aerosol mass in the past 10 years," Science, 248, pp. 996-1000 (1990); *By an analogous mechanism, anthropogenic activities may contribute atmospheric sulfur compounds and thus stratospheric aerosols.*)

9. Singer, S.F., "Does the Antarctic ozone hole have a future?," Eos, November 22, 1988.

10. Kinnison, D.E., and D.J. Wuebbles, "A study of the sensitivity of stratospheric ozone to hypersonic aircraft emissions," Lawrence Livermore National Laboratory UCRL-98314 (preprint), September 1988. *Aircraft exhausts may contribute to stratospheric sulfuric acid aerosols, observed to increase at about 5% per year in the last 10 years. See D.J. Hoffman (reference 8).*

11. Eddy, J.A., "The Maunder Minimum," Science, 192, pp. 1189-1200 (1976).

(See also "Historical evidence for the existence of a solar cycle," in Solar Output and its Variation, O.R. White, ed., University of Colorado Press, Boulder, CO, (1977 ).

12. *There are not as yet good models on the relation between sunspot number and ozone content. During periods of high solar activity, increased UV fluxes would tend to raise ozone levels; but solar proton events would destroy ozone (C.H. Jackman, NASA-Goddard Space Flight Center) as would particle precipitation into the polar zones (W.R. Sheldon, Univ. of Houston). Nor are there good models relating UV fluxes to ozone content. One problem is that different components of solar UV have quite different*

*degrees of variation during the solar cycle; i.e., as a function of sunspot number or of solar flux. For example, in solar cycle 21, Lyman-alpha (121.6 nm) shows a variation of a factor of two, while UV irradiance in the interval 200 to 250 nm varies only by a few percent. (See J. Lean, "Contributions of ultraviolet irradiance variations to changes in the sun's total irradiance," Science, 244, pp. 197-200 (1989)).*

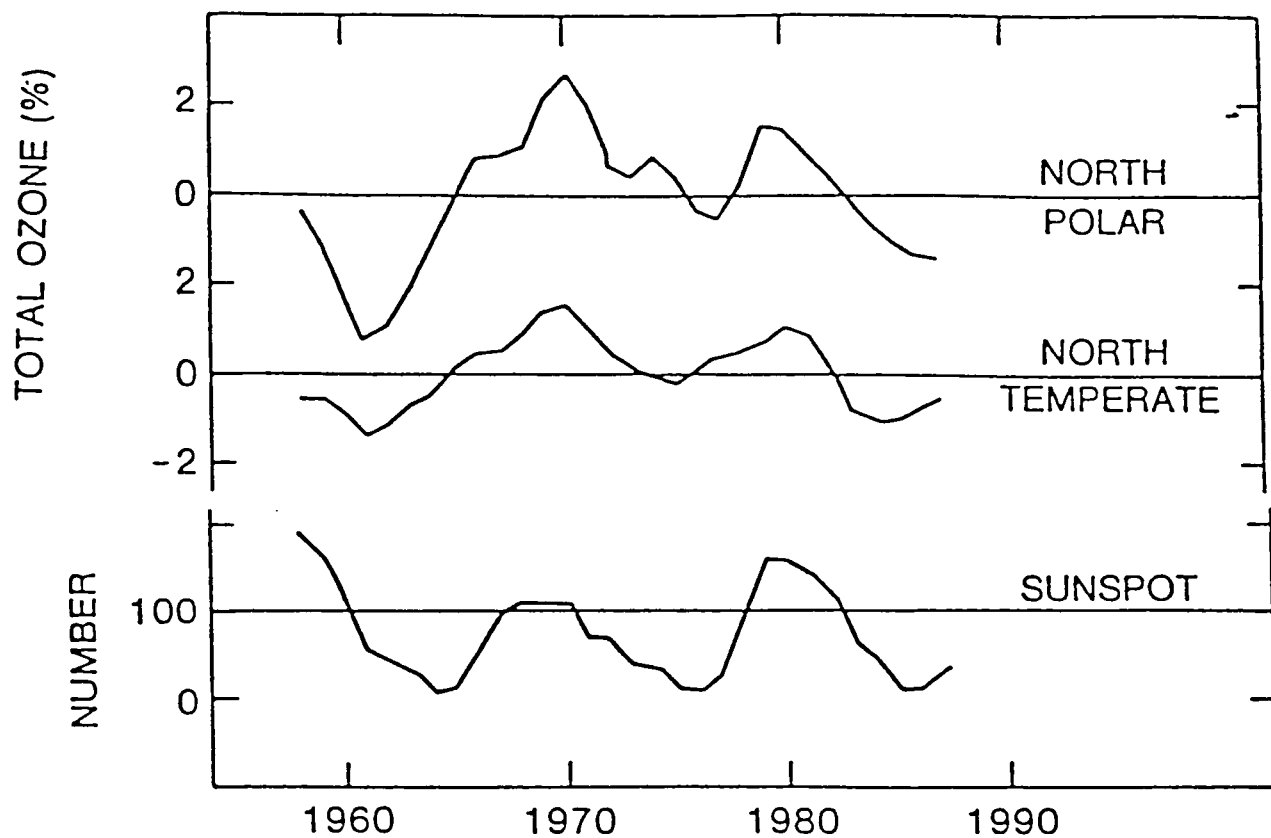


Figure 1. Total ozone change (in %) and sunspot number (Angell, 1989).

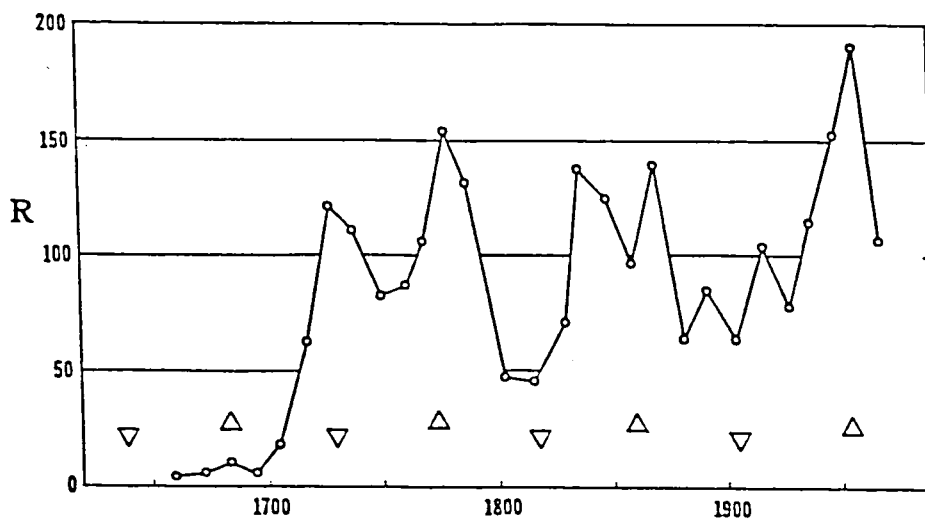


Figure 2. Annual mean sunspot number  $R$  at maxima of the 11-y cycle, A.D. 1645 to present, to demonstrate long-term trends in solar activity. Evident is the 80-year "Gleissberg cycle" (extrema shown as triangles) imposed on a persistent rise since the Maunder Minimum.